The Investment Needs Model

Appendix C: Infrastructure Table Working Paper

Provincial-Municipal Fiscal and Service Delivery Review

April 2008

Roads Investment Needs Model: Lifecycle Costs Details

Lifecycle Cost Estimation

- The model used to estimate lifecycle costs requires three key elements:
  - Inventory of existing assets
  - The timing and costs of rehabilitation and renewal events over the life of the asset
  - How long the asset is expected to last.

- For long-lived assets (e.g. over 40 years), the approximate date of construction gives the timing profile of when lifecycle events are likely to occur.

Roads Inventory

- The road infrastructure in Ontario consists of a total of just over three hundred thousand lane-kilometres of road.
  - The lane-kilometres of road were obtained from the Ontario Road Network (ORN) electronic map file.
  - The breakdown into road type is based on attribute files that are part of the ORN data.

Road type	Lane-kilometres (thousands)
Paved arterial	70
Paved collector	19
Paved local	111
Unpaved	106
Bridges	1.2
Total	307

Road Costing Model

- The following slides present the details of the road lifecycle cost model.
  - Costs are modeled for seven road categories:
    - Urban arterial – paved
    - Urban collector – paved
    - Urban local – paved
    - Rural arterial – paved
    - Rural collector – paved
    - Rural local – paved
    - Unpaved
- The assumptions used to derive the costs are presented along with a table showing lifecycle costs.
- The life cycle costs and assumptions are based on information provided by the Ontario Good Roads Association and the Regional and Single Tier Treasurers working group.

Urban Arterial Roads

- Assumptions for urban arterial cost
  - Lane width: 3.75 m
  - Road composition:
    - Surface course – 40 mm
    - Binder course – 120 mm
    - Granular ‘A’ – 150 mm
    - Granular ‘B’ – 450 mm
  - Sidewalks 1.8 m wide, both sides of the street
  - 8 driveways per km on each side of the road
  - Curbs, both sides
- Reconstruction
  - Replace 100% of sidewalks and curbs
  - Includes: tree protection fences, restored driveway connection to road, new grass, perforated pipe, sewer inspection, and contingency & overhead funding.

Urban Arterial Roads, cont'd

- Resurface
  - 50 mm mill and repave
  - 3% base repair
  - Replace 30% of curbs and sidewalks
  - Includes: new grass and contingency & overhead funding

Urban Arterial Roads – 2006 dollars			
Year	Event	Curbs etc. Cost per centreline-km	Pavement etc. Cost per lane-km
3	Crack seal	0	1,000
15	Resurface	223,000	84,000
18	Crack seal	0	1,000
30	Resurface	223,000	84,000
33	Crack seal	0	1,000
40	Reconstruct	615,000	433,000
Total cost		1,061,000	604,000
Average annual cost		**26,525**	**15,100**

Urban Collector Roads

- Assumptions for urban collector cost
  - Lane width: 3.75 m
  - Road composition:
    - Surface course – 40 mm
    - Binder course – 100 mm
    - Granular ‘A’ – 150 mm
    - Granular ‘B’ – 375 mm
  - Sidewalks 1.5 m wide, both sides of the street
  - 49 driveways per km on each side of the road
  - Curbs, both sides
- Reconstruction
  - Replace 100% of sidewalks and curbs
  - Includes: tree protection fences, restored driveway connection to road, new grass, perforated pipe, sewer inspection, and contingency & overhead funding.

Urban Collector Roads, cont'd

- Resurface
  - 50 mm mill and repave
  - 3% base repair
  - Replace 30% of curbs and sidewalks
  - Includes: new grass and contingency & overhead funding

Urban Collector Roads – 2006 dollars			
Year	Event	Curbs etc. Cost per centreline-km	Pavement etc. Cost per lane-km
3	Crack seal	0	1,000
18	Resurface	204,000	80,000
21	Crack seal	0	1,000
36	Resurface	204,000	80,000
39	Crack seal	0	1,000
50	Reconstruct	556,000	392,000
Total cost		964,000	555,000
Average annual cost		**19,280**	**11,100**

Urban Local Roads

- Assumptions for urban local cost
  - Lane width: 4.25 m
  - Road composition:
    - Surface course – 40 mm
    - Binder course – 100 mm
    - Granular ‘A’ – 150 mm
    - Granular ‘B’ – 300 mm
  - Sidewalks 1.5 m wide, both sides of the street
  - 49 driveways per km on each side of the road
  - Curbs, both sides
- Reconstruction
  - Replace 100% of sidewalks and curbs
  - Includes: tree protection fences, new grass, perforated pipe, sewer inspection, and contingency & overhead funding.

Urban Local Roads, cont'd

- Resurface
  - 50 mm mill and repave
  - 3% base repair
  - Replace 30% of curbs and sidewalks
  - Includes: new grass and contingency & overhead funding

Urban Local Roads – 2006 dollars			
Year	Event	Curbs etc. Cost per centreline-km	Pavement etc. Cost per lane-km
3	Crack seal	0	1,000
35	Resurface	204,000	89,000
38	Crack seal	0	1,000
60	Reconstruct	556,000	427,000
Total cost		760,000	518,000
Average annual cost		**12,667**	**8,633**

Rural Arterial Roads

- Assumptions for rural arterial cost
  - Lane width: 3.5 m
  - Road composition:
    - Surface course – 40 mm
    - Binder course – 100 mm
    - Granular ‘A’ – 150 mm
    - Granular ‘B’ – 300 mm
  - 8 driveways per km on each side of the road

Rural Arterial Roads, cont'd

- Rehabilitation consists of cold in-place recycling of asphalt, 3% spot base repairs, and ditching and shouldering.
- 40 mm surface course and 100 mm binder course are replaced.

Rural Arterial Roads – 2006 dollars			
Year	Event	Shouldering etc. Cost per centreline-km	Pavement etc. Cost per lane-km
18	Resurface	8,000	83,000
35	Rehabilitate	8,000	178,000
Total cost		16,000	261,000
Average annual cost		**457**	**7,457**

Rural Collector Roads

- Assumptions for rural collector cost
  - Lane width: 3.5 m
  - Road composition:
    - Surface course – 40 mm
    - Binder course – 100 mm
    - Granular ‘A’ – 150 mm
    - Granular ‘B’ – 300 mm
  - 11 driveways per km on each side of the road

Rural Collector Roads, cont'd

- Rehabilitation consists of cold in-place recycling of asphalt, 3% spot base repairs, and ditching and shouldering.
- 40 mm surface course and 100 mm binder course are replaced.

Rural Collector Roads – 2006 dollars			
Year	Event	Shouldering etc. Cost per centreline-km	Pavement etc. Cost per lane-km
20	Resurface	8,000	82,000
40	Rehabilitate	8,000	172,000
Total cost		16,000	254,000
Average annual cost		**400**	**6,350**

Rural Local Roads

- Assumptions for rural local cost
  - Lane width: 3.5 m
  - Road composition:
    - Surface course – 40 mm
    - Binder course – 80 mm
    - Granular ‘A’ – 150 mm
    - Granular ‘B’ – 300 mm
  - 11 driveways per km on each side of the road

Rural Local Roads, cont'd

- Rehabilitation consists of cold in-place recycling of asphalt, 3% spot base repairs, and ditching and shouldering.
- 40 mm surface course and 80 mm binder course are replaced.

Rural Local Roads – 2006 dollars			
Year	Event	Shouldering etc. Cost per centreline-km	Pavement etc. Cost per lane-km
25	Resurface	8,000	75,000
50	Rehabilitate	8,000	159,000
Total cost		16,000	234,000
Average annual cost		**320**	**4,680**

Unpaved roads

- Unpaved roads are assumed to need resurfacing every 3 years at a cost of $9,000 per lane-km. This amounts to a cost of $3,000 per lane-km per year.

Summary of Lifecycle Costs

- The table below presents examples of the impact on the lane-kilometre costs for various types of roads.

Summary of Average Annual Lane-Kilometre Costs ($ per lane-kilometre per year)	
Urban Arterial (4 lane)	21,731
Rural Arterial (4 lane)	7,571
Urban Collector (3 lane)	17,527
Rural Collector (3 lane)	6,483
Urban Local (2 lane)	14,967
Rural Local (2 lane)	4,840
Unpaved (2 lane)	3,000

Roads Investment Needs Model: Growth and Infrastructure Deficit Details

Road Growth Drivers

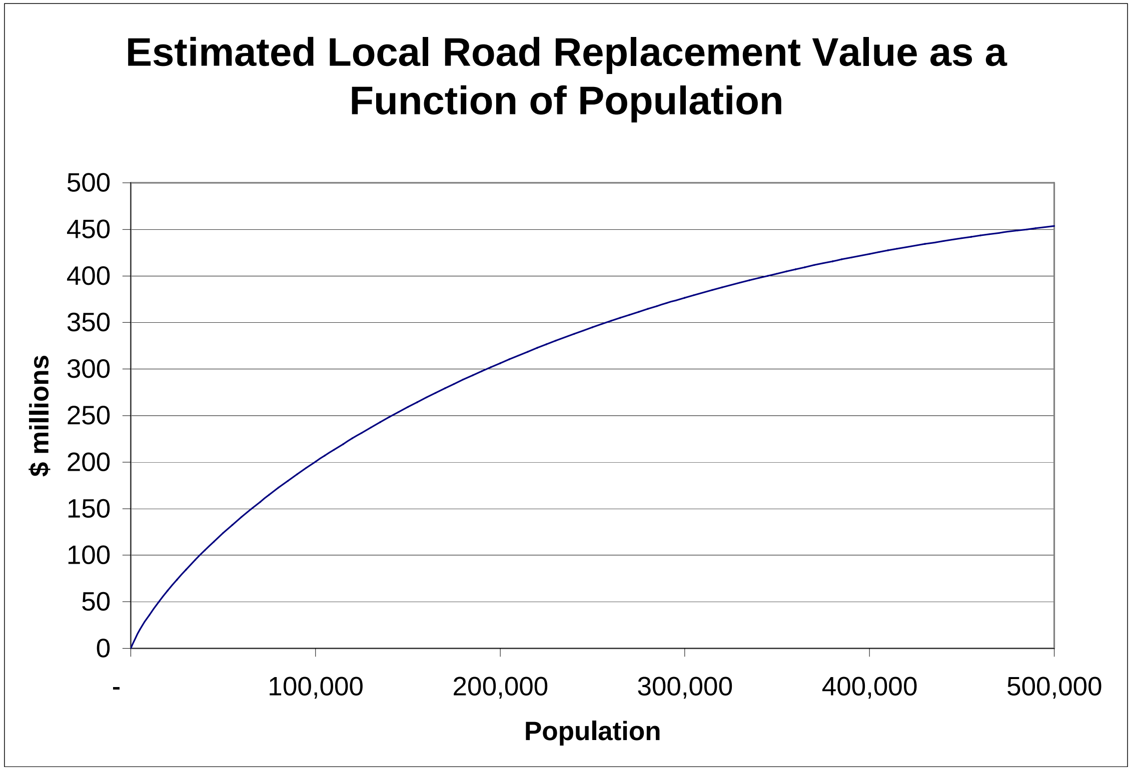
- Road infrastructure capacity is driven by several factors.
  - The extent of urban local roads is determined by growth in urbanized areas. When new subdivisions are built, new roads are needed to provide access to the new houses.
    - While all growing cities tend to expand, some of the increase in population is accommodated by increasing population density in developed areas.
    - In larger towns and cities, increasing population density accounts for a greater proportion of growth.
  - The capacity requirements of arterial and collector roads are determined by peak capacity needs. Peak capacity is generally needed during the morning and afternoon commute.
    - The main driver for traffic during these times is the population of working people in a community.

Estimating Future Need

- The Ontario Ministry of Finance has a forecast of population by census division to 2031. This data was used to calculate an average annual population growth rate for each census division.
  - The average growth rate used was the 25 year average from 2006 to 2031.
- To account for the fact that the road network does not grow proportionally to population, regressions were done at the census subdivision level to find the relationship between the replacement value of the existing stock and population.
  - The replacement value of the existing stock was estimated based on the reconstruction costs for arterial, collector, and local roads reported earlier. Although new construction is different from reconstruction, for the purposes of this estimate it is assumed that the cost of removing old pavement material is similar to the cost of preparing a new site.
  - Lane-kilometres of unpaved roads are assumed not to be increasing for the purpose of the estimate.
- The arterial and collector road inventory is assumed to be driven by working age population because peak road usage occurs during the morning and evening commute. The inventory of local roads is assumed to be driven by total population.

Roads: Estimating Future Needs

- Below is a chart of the formula for local roads in municipalities.
  - The rate of increase declines with larger populations because larger cities have higher population densities and thus fewer lane-kilometres of local road per person.



Estimation of the Existing Infrastructure Deficit for Roads

- To determine when the current stock of infrastructure will need to be replaced, age was estimated and used as a proxy for asset condition.
  - The age of roads was estimated based on Statistics Canada data on the age of the housing stock at the Dissemination Area level. The underlying assumption is that the roads in a neighbourhood would have been built at the same time as the houses were built.
  - Only roads with long lifespans are analyzed in this way.
- Once an estimate of the age of a road segment is obtained, the normal life expectancy of the road can be used to estimate when it will need to be replaced.
  - If the estimated replacement date is in the past, then it is assumed that the road needs to be replaced. It is therefore included in the infrastructure deficit.
  - If the estimated replacement date is some time in the future, the replacement cost of the road is entered as an expense in the year it is expected.
- By analyzing each road segment in this way, a time profile of replacement needs is generated that accounts for the age structure of the road system.

Estimating Road Age and the Infrastructure Deficit

- Using the installation date, the infrastructure deficit can be calculated for long lived infrastructure.
  - Local and collector roads that have exceeded their expected lifespan can be identified. The replacement cost of assets beyond their lifespan becomes part of the infrastructure deficit.

- The table below shows province-wide percentages for the amount of collector and local roads that needs to be replaced each decade for the next 40 years.

Road type	Replace now	1 to 10 years	11 to 20 years	21 to 30 years	31 to 40 years
Collector roads	12%	17%	20%	19%	19%
Local roads	17%	6%	6%	20%	20%

Bridges Methodology

Bridges: Inventory

- As with the road inventory, the lane-kilometres of bridges were obtained from the Ontario Road Network (ORN) map data.
  - An attribute field identified which centerline segments were bridges.
- There are over 880 lane-kilometres of municipal bridges in Ontario.

Bridges: Lifecycle Costs

- A value of $263,000 per lane-kilometre of bridge per year was used to estimate lifecycle costs.
  - A lifecycle cost study of roads and bridges in Kawartha Lakes that was commissioned by the City indicated that they need about $2 million per year to look after their bridges. Since the ORN map data indicated that Kawartha Lakes has about 7.6 lane-kilometres of bridges, this amounts to $263,000 per lane-kilometre per year.
- The replacement value of $11.5 million dollars per lane-kilometre was used for bridges.
  - This value was arrived at based on the lifecycle cost of $263,000 per lane-kilometre and an assumed lifespan of 60 years. It was further assumed that the ratio of rehabilitation costs to reconstruction costs was the same as that for arterial roads, 73 per cent. Thus 73 per cent of the $263,000 * 60 = $15,780,000 spent on a lane-kilometre of bridge over its 60 year lifespan is the replacement cost. 73 per cent of $15.8 million is $11.5 million.

Bridges: Growth

- Investment needs driven by growth for bridge infrastructure was estimated based on the growth of road infrastructure.
  - It was assumed that the ratio of the lane-kilometres of roads and bridges remains constant over time.

Water and Wastewater Methodology

Water and Wastewater: Introduction

- PIR has been working on a long-term water strategy for several years.
- As part of this work, detailed modeling work was done to estimate investment needs in the sector. The results of the modeling work were reported in “Watertight: A case for change in Ontario’s water and wastewater sector,” the report of the Expert Panel that was delivered in July 2005. The report and documentation on the model can be found on PIR’s [MEI’s] website.
  - Estimates of investment needs over the next 15 years were presented in the report. It was stated that “PIR’s best forecast of the need is $34 billion. The $34 billion is made up of $25 billion for capital renewal, including $11 billion in deferred maintenance, and a further $9 billion for growth.”
  - Since the release of the Expert Panel’s report, the numbers have been updated to account for inflation and minor changes to the modeling methodology. The current numbers being used by PIR[MEI] are a total need of $37 billion: $27 billion for capital renewal and $10 billion for growth.
- Using the most recent estimates of renewal investment need – $27 billion over 15 years – annual investment of about $1.8 billion is needed province-wide for existing infrastructure.

Water and Wastewater: Inventory

- Over 300 municipalities are involved in the provision of water or wastewater services.
- There are nearly 1,200 municipal treatment plants in Ontario.
  - More than three-quarters of the water plants in Ontario serve fewer than 5,000 people. More than 87 per cent serve fewer than 10,000 people.
  - Water treatment plants range in complexity from simple chlorination systems that are used in plants that draw water from high quality ground water sources to multi-step processes that involve filtration, settlement and other chemical processes to improve the quality of the water.
  - Wastewater treatment plants range in complexity from simple lagoons to multi-step processes to remove organic and chemical contaminants from wastewater.
  - Treatment facilities account for approximately 30 per cent of the value of water and wastewater infrastructure.
- Municipal utilities have almost 78,000 kilometres of water distribution and sewer collection mains.
  - Many different materials are used for water and wastewater pipes. Small diameter pipes are usually made out of cast iron, ductile iron, or plastics of various types. Larger diameter pipes are often made out of reinforced concrete.

Water and Wastewater: Inventory, cont'd

- An asset inventory survey was conducted on a sample of municipalities.

- Other sources of information used to complete non-surveyed municipalities include:
  - Information on the type of treatment and the capacity of water and wastewater facilities was obtained from the Ministry of the Environment. This data also included the number of people served by the plant.
  - To estimate the length of watermains and sewer collector pipes, road map data was analyzed. The basic assumption was that water and wastewater pipes follow roads. Data on population was used to find roads in the most densely populated regions of municipalities that serviced the number of people indicated for each plant.
  - The survey data was used to estimate the distribution of pipe diameters of watermains and sewer collection pipes.

Water and Wastewater: Lifecycle Costs

- A water and wastewater asset cost study was completed by R.J. Burnside and Associates to support the work of the expert panel. The result of their work was cost curves that could be used to estimate the cost of water and wastewater infrastructure as a function of capacity.
- The table below gives some examples of costs.

Item	Cost
300 mm PVC watermain	$569,000 per kilometre
1,000 mm concrete watermain	$2,123,000 per kilometre
300 mm PVC sewer main	$523,000 per kilometre
1,000 mm concrete sewer main	$1,205,000 per kilometre
100,000 cubic metres per day water chlorinator	$3 million
100,000 cubic metres per day conventional filtration plant	$49 million
100,000 cubic metre per day sewage treatment plant (secondary treatment level)	$185 million

Water and Wastewater: Lifecycle Cost Estimates

- The water and wastewater asset cost study also provided information on the asset's lifecycle.
  - The study provided expected lifespan for water and wastewater infrastructure.
  - It provided estimates for the timing and cost of major rehabilitation investments for each asset type.
- The lifespan of water and wastewater pipes is very long, between 60 and 100 years depending on the material. Instead of calculating an average annual lifecycle cost, age information was used to forecast when particular pipes would need to be replaced.
  - The age data was generated using Stats Canada predominant periods of construction data. The underlying assumption is that water and wastewater pipes in a region would have been installed at about the same time most of the construction happened.
- Rehabilitation was assumed to maintain the water and wastewater treatment facilities indefinitely rather than assuming they are rebuilt from scratch.

Water and Wastewater: Infrastructure Deficit

- The infrastructure deficit is estimated as follows:

  – Treatment facilities are assumed to be in a good state of repair. Treatment facilities can be easily inspected and maintenance work is done routinely to keep the facilities running efficiently and effectively. In the case of water treatment facilities, the inspections done by the Ministry of the Environment ensure that high standards are maintained.

  – For the buried water distribution and wastewater collection pipes, the infrastructure deficit was based on the estimated age of the pipes and expected lifespan. If a lifespan of 60 to 100 years is assumed depending on material type, pipes can be identified that have exceeded their expected lifespan and are due to be replaced.

  – According to the current model of investment needs, the water and wastewater infrastructure deficit is approximately $1.3 billion per year.

Water and Wastewater: Growth Needs

- The main driver of growth in water and wastewater infrastructure is population.
  - As communities grow and expand, new watermains and wastewater collection pipes are needed to serve new development. To account for increasing population density, the pipe network was assumed to expand more slowly than population growth. Analysis of the data showed that a one per cent increase in population resulted in a 0.92 per cent increase in pipe length.
  - The demand for water and wastewater treatment tends to grow proportionally to population. The Ministry of the Environment plant level data had information on both capacity and flow. Combining this with population growth data, it was possible to estimate when new capacity would need to be built. It was assumed that new capacity would be built to accommodate 30 years of future growth.
  - The water and wastewater model included a price feedback mechanism to account for the fact that if water moves to full cost recovery through water rates, demand would fall somewhat as conservation increases. This decrease had an effect on investment needs, because plant capacity expansion could be delayed in some cases.

Stormwater Methodology

Stormwater: Inventory

- Most roads have stormwater control of some sort. For the purposes of modeling, it was assumed that urban roads have storm sewers and rural roads have drainage ditches.

  – Statistics Canada uses a population density cut-off of 400 people per square kilometre to differentiate between urban and rural areas. Their definition has some added complexity to account for isolation.

  – For the purposes of determining whether roads have ditches or storm sewers, roads within half a kilometre of a Statistics Canada Dissemination Area with a population density over 400 people per square kilometre are considered urban and thus are assumed to have storm sewers. All other roads are assumed to have drainage ditches.

Stormwater: Inventory, cont'd

- The Ontario Road Network data was used to identify the location and length of roads.
  - The number of lanes a road has was assumed not to affect the cost or number of storm sewers and drainage ditches.
  - When roads have barriers such as boulevards or street car stops that divide the paved surface, the Ontario Road Network has separate lines for each section of the paved surface. There was no systematic way to remove the double counting of these road sections. Visual inspection of the map data shows that the double counting is not a widespread problem.
- From this analysis, it is estimated that the total length of urban roads in Ontario is 45,000 kilometres. The length of rural roads in Ontario is 109,000 kilometres.
- According to OGRA, the replacement cost for a kilometre of storm sewer is $632,000. The cost to replace drainage ditches along a kilometre of roads is $100,000.
- The value of storm sewers and ditches is large. Province wide, the total replacement cost is about $39 billion.
  - Storm sewers are worth about $28 billion, a little over 70 per cent of the total.
  - Drainage ditches make up the remaining $11 billion.

Stormwater: Inventory, cont'd

- Of the $39 billion estimated replacement cost, $25 billion is in census divisions with major centers and $14 billion is in census divisions without major centers.
- Due to higher population densities, the value per person is much lower in census divisions with major centers: $2,600 in census divisions with major centers versus $6,000 in the other census divisions.
- The value of infrastructure in central Ontario is the least per capita. In the north the value is the highest per capita.

Region	Replacement value ($ billions)	Replacement value per capita ($)
Central	13	2,100
East	8	4,400
West	14	4,100
North	4	5,700
Total	39	3,300

Stormwater: Lifecycle Costs

- The lifecycle capital costs of storm sewers and drainage ditches consist only of the initial construction costs. No capital rehabilitation work is done to extend the useful life of storm sewers or ditches.

- Based on analysis from OGRA, for the purposes of modeling, the useful life of storm sewers is assumed to be 100 years and the useful life of drainage ditches is assumed to be 50 years.

- To account for the age of storm sewer pipes, the analysis on the age of sewer mains was used as a starting point.
  - The age data for the entire sewer pipe network was extracted from the water and wastewater model.
  - The 100-year lifespan was used to estimate when each section of pipe would need to be replaced.
  - A time series of investment need was generated using the replacement timing from the model and the cost per kilometre from OGRA.

Stormwater: Infrastructure Deficit

- The analysis used to generate the time series of investment needs for storm sewers also identified pipes that had exceeded their useful lifespan.
- Because of the long lifespan of storm sewers, 100 years, they are only just beginning to need replacement.
  - The estimate of the deficit for storm sewers is much smaller than both water and wastewater infrastructure deficits, because of the long lifespan.

Stormwater: Lifecycle Cost Estimates

- The lifecycle capital cost for storm sewers and drainage ditches is found simply by multiplying the average annual cost per kilometre by the number of kilometres for each infrastructure type.
- Province-wide, $500 million is needed for storm sewers and drainage ditches.
  - In census divisions with major centres, $280 million is needed annually. This amounts to $29 per person.
  - In census divisions without major centres, $220 million is needed annually. This amounts to $92 per person.

Stormwater: Growth Estimate

- For the most part, storm drainage is built when roads are built.
  - Storm sewers are usually located beneath streets.
- To estimate growth needs for storm water infrastructure, it was assumed that the stock of stormwater infrastructure would grow proportionally to the stock of road infrastructure.
- Since the growth of road infrastructure has already been modeled, estimating the growth in storm sewer infrastructure is reduced to simple calculations of ratios.

Transit Methodology

Bus Transit: Inventory

- The inventory of buses was obtained from the Canadian Urban Transit Authority (CUTA). CUTA has information on 54 urban transit systems.
- CUTA collects counts of buses by type:
  - Standard 40 foot bus
  - Articulated bus
  - Double decker bus
  - Community bus
- Across the province, CUTA reports that there are 4,464 standard buses, 300 articulated buses, one double decker bus, and 100 smaller community buses.

Bus Transit: Lifecycle Costs

- Unit costs for buses were obtained from the Ministry of Transportation.
- It is assumed that all standard and oversized transit buses purchased in the future will be hybrid diesel electric. This increases costs by about $225,000 per bus.
- Buses are assumed to have a lifespan of 12 years.

Type	Unit cost ($)
Standard bus	619,440
Articulated bus	789,032
Double decker	789,032
Community bus	100,000

Bus Transit: Growth

- Growth costs for transit are estimated in a way that is similar to how growth costs are estimated for roads and bridges.
  - A regression is performed to identify the relationship between capital costs and total annual rider-trips.
  - Annual rider-trips are assumed to grow proportionally to population.

Light and Heavy Rail Transit: Lifecycle Costs

- Since the Toronto Transit Commission (TTC) has the vast majority of light and heavy transit rail in the province, it was analyzed in detail.
  - Staff at the TTC indicated that they thought capital reinvestment by the TTC is approaching a long-term sustainable level.
  - The TTC’s 2008 to 2012 capital plan contains forecasts for investment required over the next 10 years. A 10 year average of non-growth related investments is used as an estimate of long-term investment need.
- For the O-train in Ottawa, track costs were assumed to be similar to subway track costs. The cost of the train sets and the length of track was obtained from press releases.
  - The costs associated with maintaining the roads in Ottawa’s Bus Rapid Transit system were not included in transit costs.

Light and Heavy Rail Transit: Growth

- Future investments in light and heavy rail were estimated based on the announced provincial MoveOntario 2020 program. The plan is to invest just over $14 billion by 2020.
  - It is assumed that the announced projects will be completed.
- From 2021 to 2045, it is assumed that the same total will be invested in new projects. Since the timeframe is longer, the resulting rate of investment is considerably slower.
  - Funding was divided among growing Census Divisions with 2045 populations over 300,000. Based on the assumption that new projects would service growth, funds were allocated proportionally to the increase in population in each Census Division.

Conservation Authorities Methodology

Conservation Authorities Inventory

- The Grand River Conservation Authority maintains a central database of flood and erosion control structures on behalf of all Conservation Authorities in Ontario.
  - The database provides information on the age of the structure and its estimated replacement cost.
  - While the database does not have information on every small flood control structure in the province, for the purpose of this analysis, it has been assumed that all large dams (with replacement value greater than $1M) have been documented and accounted for in the database.

- Approximately 114 dams in Ontario under the ownership and management of Conservation Authorities have an estimated replacement value of $1M.
  - While these dams are found throughout the province, the majority of them are located in South-western Ontario.

Large dams (Replacement value > $1 M) Distribution among Ontario's regions.

Region	Number of Structures	Replacement Value
East	12	$46M
West	73	$616M
North	16	$62M
Central	13	$42M
TOTAL	114	$767M

Conservation Authorities Lifecycle Costs

- Due to the nature of dams and the storm events they are constructed to manage, lifecycle costs of dams are highly variable.
  - There are dams in the province that were built before WWII that have received little in the way of major rehabilitation.
  - For example, Springbank dam in London was built in 1929 and has an estimated replacement value of $10M. It is currently undergoing a major rehabilitation project worth approximately $6M.
- The lifecycle cost model developed for this analysis is based on information provided by the Grand River Conservation Authority database.
  - Lifecycle cost estimates are based on the assumption that structural rehabilitation occurs every 60 years, at a cost of 30% of the structure’s total replacement value.

Waste Methodology

Methodology

- Asset inventories, replacement costs, and life spans were obtained from the Cities of Toronto and Hamilton.
- Replacement costs were divided by the median life span to calculate a replacement cost per year
- These annual replacement costs were scaled by the amount of waste landfilled, recycled, or composted, as appropriate, to create costs per tonne for each type of waste.
- For a given diversion, compost, and incineration rate, these costs are then summed for each tonne of waste to generate an overall replacement cost per tonne.
- These replacement costs were then scaled to other municipalities using the average per capita waste production and municipal population sizes.

Inventory & Lifecycle Costs

Asset Type	Asset Component	Unit Replacement Cost	Life span	Annual cost/tonne
Landfill	Landfill	$103,200,000	55-100	$14.94
	Leachate Collection/Treatment	$2,000,000	25	$1.97
Processing	Transfer Stations	$5,000,000	40-50	$1.35
	Community Recycling Centres	$3,000,000	25	$7.97
	Leaf and Yard Waste Composting	$2,000,000	15-20	$3.06
	Materials Recycling Facility	$18,000,000	40	$9.97
	Central Composting Facility	$35,000,000	25	$36.45
Vehicles	Collection	$169,407	10	$6.21
	Transfer	$165,812	10	$2.27
	Processing	$199,845	10	$0.18
	Disposal	$211,361	10	$1.07
	Litter Collection	$45,392	10	$0.48
	By-Law Enforcement	$33,040	10	$0.08
	Maintenance	$55,418	10	$0.17

Model Parameters

Parameter	**Value**
Diversion rate	22%
Compost rate	45%
Incinerate rate	0%
Landfill cost	$25/T
Compost cost	$41/T
Recycle cost	$20/T
Incinerate cost	$30/T
Annual waste per capita	1T

Data Sources

Information sources for modeling

The information and assumptions used in the modeling work are from several sources:

Description of information	Source
Road lifecycle and cost information	Ontario Good Roads Association
Road inventory	Ministry of Natural Resource's Ontario Road Network geospatial database
Population Data Age of housing stock	Statistics Canada's 2006 Census
Population forecast	Ministry of Finance
Information on water and wastewater treatment plants	Ministry of the Environment
Costing data for water and wastewater infrastructure	Study completed by RJ Burnside
Bus inventories	Canadian Urban Transit Association
Bus lifespan and cost data	Ministry of Transportation
Toronto transit data	Toronto Transit Commission
Modeling assistance and municipal specific data	Regional and Single Tier Treasurer Infrastructure Deficit Working Group.